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DESIGN AND DEVELOPMENT

OF SILVER-CADMIUM STORAGE BATTERIES

Third Quarterly Report

Contract No. NAS5-1318

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
GODDARD SPACE FLIGHT CENTER
GREENBELT, MARYLAND

THE EAGLE-PICHER COMPANY
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January 1, 1962 to March 31, 1962

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PURPOSE

To improve the power output per unit weight of a power supply for an orbiting vehicle, the development of a sealed silver oxide-cadmium battery has been initiated. This battery development contract specifies that the requirement of a basic 5 ampere-hour cell capable of cycling for one year at a cyclic frequency of 100 minutes. In addition to cycling, other testing and support development work must be performed. Basically, the other major phases of work to be performed are:

1. The improvement of seals to eliminate or minimize leakage during cycling and stand.
2. Separation evaluation studies to improve the cyclic life of a sealed silver oxide-cadmium cell.
3. Minimize the magnetic properties of the cell.
4. Establish the dynamic testing levels for the cell design.
5. Improve the power output per unit weight.
6. Determine the operating characteristics and activated stand characteristics of the cell at various temperatures.
7. Perform tests to evaluate the couple for extended overcharge periods and to establish the operating pressure as a function of the overcharge current.

I. INTRODUCTION

During this reporting period, tests were initiated to better evaluate the cyclic life capabilities of the silver-cadmium system. The cells used for these tests are of the prismatic or rectangular configuration as described in the Second Quarterly Report to NASA.

The following cyclic tests are presently being performed.

(1) A 10% depth of discharge at +80°F at an absolute pressure of less than 100 microns.

(2) A 10% depth of discharge at +20° F at normal atmospheric pressure.

(3) A 10% depth of discharge at +120° F at normal atmospheric pressure.

(4) A 10% depth of discharge at +80° F at normal atmospheric pressure.

To better evaluate the performance of the silver-cadmium system when subjected to very deep discharges, another cyclic test was initiated. This test consists of a 5 ampere-hour discharge over a 2-hour period, and an 18-hour charge at a constant voltage of 1.50 volts per cell with the current limited to 2.0 amperes. Since the original capacity of these cells was only approximately 6 ampere-hours and with some capacity loss during the initial cycling, this test consists essentially of an 100% depth of discharge.

During this period of work, the magnetic properties of the cells were minimized. All materials presently being used in the fabrication of test cells have minimum magnetic properties and have been proven suitable for long cyclic operation.

Cells of the present design were subjected to limited dynamic testing. Testing included vibration, shock and acceleration at levels that should normally be adequate, or more than adequate for orbiting vehicles.

II. DISCUSSION

A. Cell Materials

1. Plate Materials

The bulk of the effort expended during this reporting period was directed towards the design, fabrication, and initial testing of sealed cells constructed from unformed plates. Since this concept of cell design was not used in previous investigations, many items had to be tested before a suitable cell was fabricated. Cells were fabricated using sintered silver positive plates and pasted cadmium oxide negative plates. Cells using unformed active materials can be produced much cheaper than would normally be expected. In fact, in a production run of cells, the cost could be greatly decreased by using the unformed plate construction.

2. Grids

It was stated in the Second Quarterly Report to NASA that two new grid materials had been received which might possess suitable electrical conductivity and magnetic properties for this particular application. These two materials were cupro-nickel and 18% nickel silver. The magnetic properties of these materials were found to be excellent. However, the electrical resistivity of both materials was excessively high. This high grid resistance produced a noticeably lower voltage level during discharge of the test cells. It was decided, therefore, to use silver grids on both the positive and negative plates. However, in all cell fabrication, stainless steel plate tabs are used as connectors between the grid and the terminals. This prohibits the possibility of complete oxidation and subsequent failure of the current-carrying plate tabs which might occur if silver grid or wire was used.

3. Terminals, Cans and Covers

The terminals used in all cell construction are machined from 300 series stainless steel thereby minimizing the magnetic properties. The cans and covers used in all test cells are drawn from a Type 321 stainless steel. This material has excellent magnetic properites and is very easy to weld.

4. Terminal Seals

The seal that has been used on all test cell fabrication has been of the Teflon compression "O"-ring type. While this seal is far from the ultimate, it has proven superior to available glass seals.

Several commercial manufacturers of ceramic seals have been approached with the thought of obtaining a ceramic seal that would be suitable for this operation. Several sample seals have been obtained and are presently being tested in an oxygen and KOH atmosphere. At this time, no vastly superior ceramic seal has been found. However, there is the possibility that some of those seals presently being tested will prove reliable.

Since some difficulty was encountered during the last period in obtaining a good terminal seal in test cells, the cell cover was redesigned to allow a greater amount of compression on the "O"-ring. With these new covers, a much better seal has been affected and a higher degree of reliability can now be assured.

5. Separator Materials

The separators used as an insulating membrane in the test cells fabricated during this period contained cellophane and various combinations of cellophane and RAI separators. Past testing and the limited testing done during this quarter indicated that the RAI separation is not

superior to cellophane for normal temperature cell usage and has the disadvantage of being very costly. Therefore, all the latest test cells are fabricated using multiple layers of cellophane as a membrane separator.

A more thorough examination of separator materials is being conducted under a basic study for the Signal Corps. As results are obtained, they will be made available to NASA. One place where the RAI separation may prove vastly superior to cellophane is at the higher temperature levels. Our testing has indicated that as the temperature of operation is increased to a temperature above 100° F, a rapid deterioration of the cellophane is experienced. It may, therefore, be necessary to add some other type separation such as Permion 300 to the construction of these cells to insure long cyclic life at high temperatures.

B. Cell Fabrication Procedure

With the exception of minor changes in techniques that were necessary for the handling of the unformed cadmium oxide plate, the basic cell construction procedure has remained the same. To utilize the unformed plates, the number of plates per cell was decreased from seven positives and eight negatives to four positives and five negatives. This decrease in the number of plates in each cell increases the current density during discharge. However, for the rates for which this cell was designed to operate, the voltage difference is very slight.

One major change that was made during this reporting period was the isolation of the negative terminal from the cell case. Previous cells were constructed with the negative terminal grounded to the can and an external terminal silver soldered to the cover. This procedure had one advantage over the present construction of two isolated terminals. This advantage was that there was only one seal to perfect. The process used

for making the negative terminal to can connection was a difficult operation and not conducive to assembly line technique. The cell in which both terminals are isolated from the container is much easier to make and a more uniform and reliable cell is the end product. The fabrication procedures and controls, which were previously used in all Eagle-Picher dry charged batteries, have been carried over to the fabrication of the unformed plate cells. Each group of plates is visually inspected and weighed to assure that a reliable end product is obtained. The maximum weight differential that is allowed in the plate groups of a cell of the size that is being used for this operation is ±1.0 gms. Under these controls, a very consistent capacity can be obtained from each cell.

C. Cell Formation

To properly form the plates in the cell, it has been found that a minimum of five charge and discharge cycles are required. All cell formation has been done by controlling the maximum voltage drop across each cell to 1.50 volts per cell. The maximum current that has been used for formation is 2.0 amperes and the current decreased as the cell voltage reaches 1.5 volts. The cells are considered charged or formed when the current decreases to a level below 50 milliamperes. The time interval required to obtain the original formation is usually about 16 to 20 hours. On each subsequent charge and discharge cycle, the capacity of the cells will increase slightly for the first five cycles and after that time, level off at a constant ampere-hour output of approximately 6.5 ampere hours. This capacity can be increased by allowing the cells to charge for longer periods of time. It has been found that by allowing the cell to charge at 1.5 volts constant potential for approximately five days, the capacity of the cell can be increased to almost 9.5 ampere hours.

Since the charge efficiency is very high at a 1.5 volt constant potential charge, very little gas is evolved and the internal pressure of the cell is usually very low.

D. Cell Testing

1. Testing of Cylindrical "D" Cells

The cyclic testing of the "D" cell battery was terminated during this reporting period. The nine-cell battery had completed 1329 cycles before a low discharge voltage on one of these cells was noted. At this time, all cells were removed from the vacuum chamber and individually charged. The cells were then individually discharged to establish the rate of loss of capacity as a function of cyclic life. Table No. IX shows the original capacities of the cells and the capacities that were obtained from the cells during the 1330th discharge. The table also shows that there is no set pattern for the capacity lost over a definite cyclic period. To further evaluate the reasoning for the extreme loss in capacity of some of these cells, the cells were recharged and placed on open circuit stand. After an open circuit stand of 20 hours, only four of the cells still possessed an open circuit voltage of 1.40 volts or above, thus showing a certain degree of internal shorting. These four cells, which are designated by asterisks in Table No. IX, were then placed back on automatic cycling, and the cycling resumed at 1331 cycles. The cyclic frequency remains at 100 minutes with a 40-minute discharge and a 60-minute charge. The depth of discharge is still 10% or 0.5 ampere-hour output. After completing 350 additional cycles, the end of discharge voltage of Cell No. 3 was found to be below 0.9 volt and the test was then temporarily halted and this cell removed. The discharge load was reset to maintain a

10% depth of discharge and the cycling continued. The remaining three cells have completed 1797 cycles to date with no indication of failure.

A "post mortem" was performed on all cells which had been removed from this test. In each case, a definite breakdown in the separation was noted, and in every case, this breakdown in separation occurred at the point of connection of the tab to the plate. In cylindrical cell construction, it appears that this point of connection must be more heavily separated to compensate for any possible roughness at points of high current density operation.

2. Cyclic Test at +20° F

One battery consisting of ten rectangular cells connected in series was subjected to cycling testing at a temperature of 20 ± 1° F. This test, which is being performed at atmospheric pressure, consists of removing 0.5 ampere-hour in a 40-minute time interval and charging at a modified constant current, constant voltage of 1.5 volts per cell for 60 minutes. To date, this battery has completed 910 cycles of charge and discharge with no indication of any cell failure or irregularity.

The cells of which this battery is comprised were fabricated using the standard dry-charged plates.

The battery is monitored daily and the end of charge and discharge cell voltages are recorded. The end of charge and end of discharge voltages have remained very consistent throughout the entire test as can be seen in Table No. X. However, there has been a slight decrease in the operating voltage of the battery. Figure No. XV is a plot of the discharge voltage of the battery during its initial discharge cycle and also, during its 910th discharge cycle. From these discharge curves, it can be seen that there is a definite loss of divalent oxide voltage over this

limited number of charge and discharge cycles. This decay of the divalent oxide voltage level was anticipated since the charging of the cells is controlled at a voltage that is low enough to prohibit the formation of any appreciable amount of the higher oxide during these short charge intervals.

3. Cyclic Testing at 120° F

A battery consisting of 10 series connected rectangular type sealed silver-cadmium cells was subjected to cyclic testing at 120 ± 2° F. The test, which was conducted at atmospheric pressure, consisted of a 40-minute discharge and a 60-minute charge. During the discharge interval, 0.5 ampere-hour was removed. The charge voltage was controlled at 1.50 volts per cell, or 15 volts for the entire 10-cell battery. Charging current is limited to a maximum of 2 amperes, with the current decreasing as maximum battery voltage was reached.

During the life of the test, the end of charge and end of discharge voltage of each cell was recorded. Table No. XI shows the end of charge and discharge voltages as they were recorded. It can be seen that these charge and discharge voltages varied greatly in some cells while others remained fairly constant throughout the test.

After completing 624 charge and discharge cycles, the end of charge voltage of Cell No. 41 was very low and it was apparent that the cell had a small internal short. Because of this low cell voltage, the test was temporarily halted while Cell No. 41 was removed from the battery package. While the cell was being removed from the battery, and the charge and discharge circuit re-adjusted, the battery was on open circuit stand at room temperature. After the battery had been on stand overnight at the room temperature, a routine check of the cell open circuit voltages

was made. It was found at this time that the open circuit voltage of one other cell was also low. A "post mortem" of the two minutely shorted cells revealed severe deterioration of the separators. It was decided at this time to leave the remaining cells on open circuit stand and to monitor the open circuit voltage periodically. After an open circuit stand period of approximately 48 hours, all but two of the cells had shown a decrease in open circuit voltage. The remaining cells were then "post mortemed" and a similar deterioration of the separator was noted.

The separation utilized in the construction of these cells consisted of four wraps of 600 Cellophane and one wrap of RAI Permion 300. The inert separation next to the positive material was woven nylon. The "post mortem" revealed that while the cellophane had almost completely deteriorated, the Permion was still fairly strong but completely coated with silver, and electronically conductive when dry.

Figure No. XVI is a graph of battery voltage versus time for two discharges that were made during the cycling at 120° F. It can be noted that the decrease in divalent oxide voltage was much more rapid and occurred over many fewer cycles that it did at 20° F.

4. 80° F Cyclic Test in Vacuum Chamber

This test is being performed on a 10-cell battery that was fabricated from unformed plates. The cells were formed and subjected to approximately ten conditioning cycles prior to the start of this test. The battery was placed in a vacuum chamber and the chamber connected to a mechanical vacuum pump. The absolute pressure that is maintained in the vacuum chamber is less than 100 microns of mercury absolute. The cyclic frequency of the battery is 100 minutes with a 40-minute discharge and a 60-minute charge. The depth of discharge is 10%, or an output of 0.5

ampere-hour. Daily recordings are taken of the cell end-of-charge and end-of-discharge voltages.

Table No. XII shows the end-of-charge and end-of-discharge voltages at the end of various cycles. The table shows that the charge and discharge cell voltages have remained quite consistent throughout the entire testing to date. It is felt this consistency will continue until one cell begins to fail at which time the other cells will accept a greater charging voltage.

Figure No. XVII is a graph of the battery voltage versus time for the 1st and 615th discharge of this battery. During the first discharge cycle, the entire battery voltage was maintained at the divalent oxide level. After 615 cycles, the divalent oxide level of voltage has decreased to almost 25% of the total discharge. This indicates that the charging time interval is not long enough to completely charge the cell. On the initial charge and discharge cycle, the output of the battery greatly exceeded that which could be replaced in the 60-minute charge interval. After 615 cycles, the input was slightly larger than the output.

5. 5 Ampere-Hour Cyclic Test

To evaluate the silver-cadmium system from the standpoint of very deep depths of discharge, a cyclic test was started that would allow a discharge of 5 ampere-hours over a two-hour period, and a recharge consisting of 18 hours of modified constant potential charging at 1.50 volts per cell. This test is being conducted at 80° F and at normal atmospheric pressure. Because of the extended time interval to complete a charge and discharge cycle, only limited information is available at this time.

Table No. XIII shows the end-of-charge and end-of-discharge voltage of each of the cells in the battery. While there has been some slight variation in the end-of-charge voltage, and a slight decrease in the end-of-discharge voltage, as a whole the voltages have remained very constant.

Figure No. XVIII is a graph of battery voltage versus time for the 1st and 54th discharge of this battery. These two curves show that the battery divalent oxide voltage has actually increased over these longer charging intervals. At the same time, the discharge voltage has decreased but only slightly.

The cells in this battery were fabricated from unformed plates. It is felt that the cyclic life of this battery will be a function wholly of the life of the separation.

E. Cell Dynamic Testing

During this reporting period, limited dynamic testing was performed on single cells. The dynamic testing was conducted at a level which should, however, be in excess of that encountered during the launch phase of an orbiting vehicle. The tests to which the single cells were subjected are as follows:

(1) Vibration

Frequency	G Force or Double Amplitude
5 to 20 cps	0.5 inches
20 to 500 cps	10 g
500 to 2000 cps	15 g

Note: Total sweep time for each plane was 15 minutes.

(2) Shock

Time each Plane	G Force
10 ms	100 g

(3) Acceleration

Time each Plane	G Force
15 min.	50 g

During all dynamic testing, the cells were being discharged at a constant resistance of 1.45 ohms. Cell voltages and currents were recorded.

In addition to the above mentioned tests, the cells were subjected to 30 minutes of constant acceleration at a 100 g force level with the terminals out. This is by far the worst position for operation since the electrolyte could be forced from the plates to the void around the terminals and thus cause a shortage of electrolyte for operation.

Vibration, shock and acceleration were performed in all three perpendicular planes and no adverse affects from the testing was noted.

During the next reporting period, a complete 10-cell battery will be subjected to the same level of dynamic testing and single cells will be tested to higher levels to determine the limit of the design.

F. Performance of the Silver-Cadmium Couple

1. Introduction

It has become apparent that the silver oxide-cadmium system can be divided into two definite subsystems. The optimum system would utilize the potential energy available from both the higher and lower oxide states of silver. The second system would operate only at the lower capacity potential of the positive plate.

Unfortunately, continuous operation of a sealed cell utilizing the power potential from the higher oxide state, or divalent silver oxide level, multiplies the inherent problems associated with obtaining long cyclic life of a sealed cell assembly.

The lower state of silver oxidation, or monovalent oxide has definite advantages from the standpoint of increased cyclic life and excellent voltage control, at the sacrifice of capacity.

2. The Divalent Silver Oxide-Cadmium System

Initial investigation of sealed cells utilizing the maximum potential power of the divalent silver oxide revealed several inherent problems. The most significant problem was the fact that the charging of the positive plate from the monovalent oxide state to the divalent oxide state is less efficient than the oxidation from metallic silver to monovalent silver oxide. During the charging process to the higher state of oxide, oxygen is evolved. Unless a relatively high rate of recombination can be achieved, excessive oxygen pressures are developed even at low rates of charge. This recombination can be achieved by increasing the area of cadmium plate and by operating the cell in a semidry state. This condition, however, is incongruent with long cyclic life and high output per unit weight. To increase the available cadmium area for recombination, a greater number of thin plates must be used, thus increasing the relative amount of inactive material such as grids and separators.

However, by compromising the design of produce a medium high output and recombination at approximately the 40-hour rate, a 10 ampere-hour cell can be fabricated that will produce approximately 25 watt-hours per pound. The same cell, when operating at the monovalent oxide level, will produce only approximately 16 watt-hours per pound.

Since an appreciable part of the weight of the cell is the heavy container, these figures can best be compared on the basis of theoretical capacity of the positive plate. Table No. IX shows the comparison of two identical cells with respect to energy output. These cells were fabricated to extremely close tolerances with each cell containing the same amount of sintered silver. The cells were individually charged at the recorded voltages for 16 hours and discharged at a constant 2.0 ampere rate. A comparison of the results shows the definite power output superority when the cell is operated at the divalent oxide level. The slight loss of capacity that can be seen after the second cycle may be accounted for by a slight loss of silver to the separators. This is common in all cells regardless of the charging potential. However, this slight decrease will continue for only about 20 cycles and then the rate of decrease becomes negligible.

The pressure differential in the two cells was considerable. The cell charging at 1.50 volts maintained an internal pressure of less than 20 psi at all times, while the pressure of the cell charging at 1.70 volts, was at times in excess of 300 psi. While this high pressure is definitely undesirable, the extra power output does appear to warrant more investigation.

3. The Monovalent Silver Oxide-Cadmium System

The monovalent silver oxide-cadmium system appears to have a greater potential for achieving long cyclic life. Apparent advantages that the monovalent silver oxide-cadmium system has for achieving long cycle life are as follows:

a. Operating a positive plate at its lower state of oxidation should extend separator life due to its lower oxidation potential.

b. Since the oxidation of silver to the monovalent state is exceptionally efficient, the cell would operate at a low internal pressure.

c. Maintaining the positive plate at the lower state of oxidation would increase the plate's matrix structure thus minimizing the shedding of active materials.

d. By controlled charging, an extremely fine discharge voltage control can be achieved.

These advantages appear to indicate that the preferable couple would be the monovalent silver oxide-cadmium system. However, the system per se does not meet the requirements of a truly sealed system where recombination is essential for operation. A standard plastic case cell, when fitted with a low pressure relief valve (15-20 psi) should be capable of performing in any atmosphere, as long as the charging voltage is controlled to 1.50 volts maximum.

3. Recommendations

It is felt that basic research should be performed to better evaluate and compare the two basic silver-cadmium systems, especially with respect to their maximum capabilities. It is more than conceivable that both systems have a definite place in the family of military power supplies.

III. SUMMARY

1. Cyclic testing of cells fabricated from unformed active materials was initiated.

2. Cyclic testing of a ten cell battery at 20 ± 2° F was initiated and has completed 910 cycles to date.

3. Cyclic tested of a ten cell battery at 120 ± 2° F was terminated after 624 cycles due to a complete breakdown in separation.

4. Three "D" cells have completed 1797 cycles at a depth of discharge of 10%.

5. The magnetic properties of all test cells have been minimized through the selection of applicable components.

6. Single cells have been subjected to limited dynamic testing.

IV. PROGRAM OF WORK FOR THE FOURTH QUARTER

The following is a list of investigations to be made during the final quarter of this contract.

1. Procure and test ceramic seals from various commercial manufacturers.

2. Dynamically test a complete ten cell battery of the final design to the test levels explained in this report.

3. Perform single cell dynamic testing at a higher level to determine the failure limit.

4. Initiate further separation studies for the evaluation of new separator materials.

5. Continue the cycle life studies that have begun during the third quarter.

V. DISTRIBUTION OF ENGINEERING HOURS AND MATERIALS

The following is a list of engineering personnel and technicians associated with this contract, the hours of work performed by each, and the cost of materials purchased during the third reporting period:

NAME	TITLE	HOURS
Morse, E.	Senior Engineering Supervisor	59
Sieglinger, F.	Project Engineer	150
Dittmann, F.	Battery Engineer	113
Broglio, E.	Battery Engineer	33
Call, D.	Battery Engineer	512
George, J.	Battery Engineer	77
Carr, D.	Technician	533
Cook, A.	Technician	543
	TOTAL	2,030

Purchased Material Costs . . . . . $ 2,001.42

A P P E N D I X

K+E 10 X 10 TO THE ½ INCH 359-11
KEUFFEL & ESSER CO. MADE IN U.S.A.

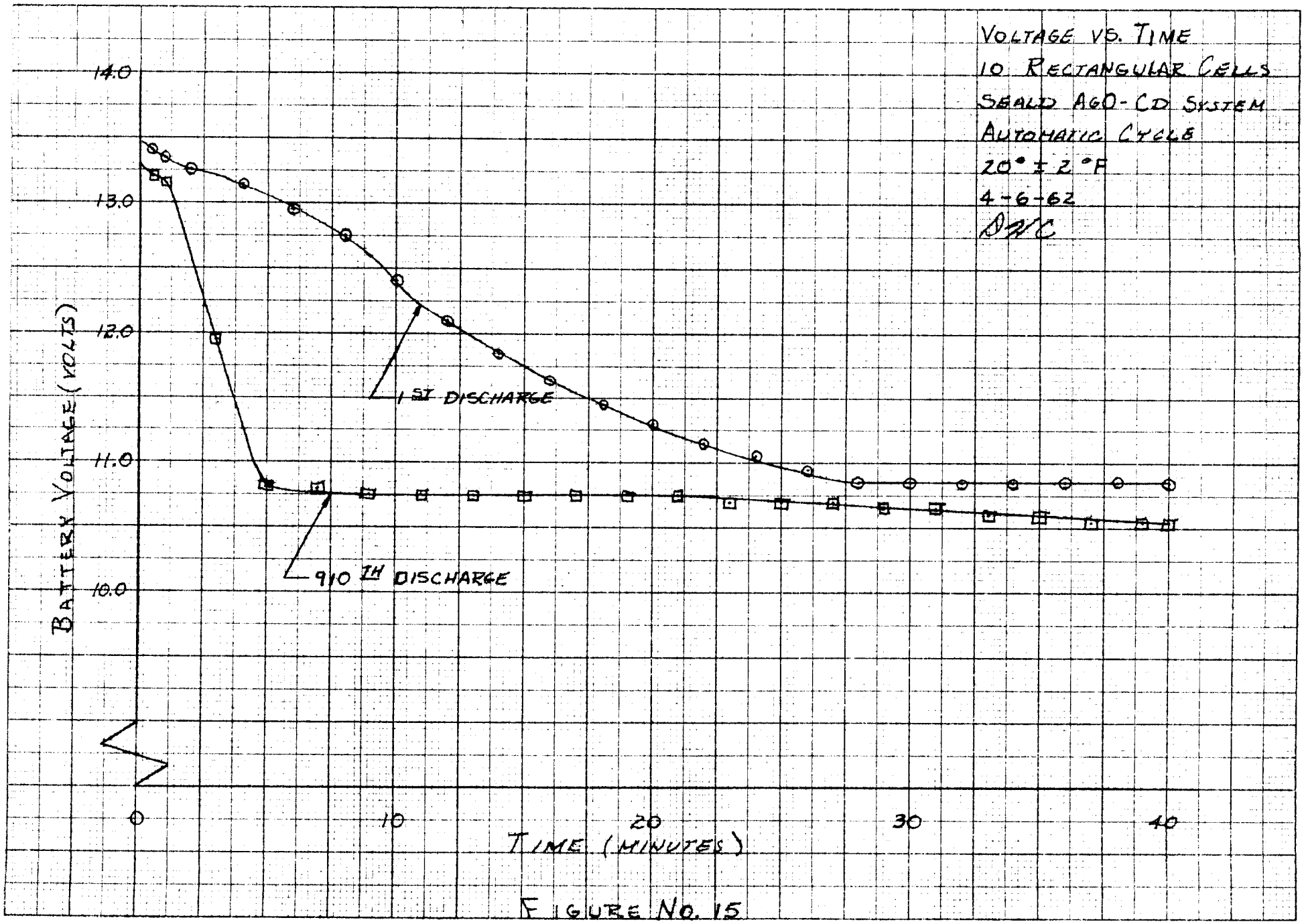

FIGURE NO. 15

K+E 10 X 10 TO THE ½ INCH 359-11
KEUFFEL & ESSER CO. MADE IN U.S.A.

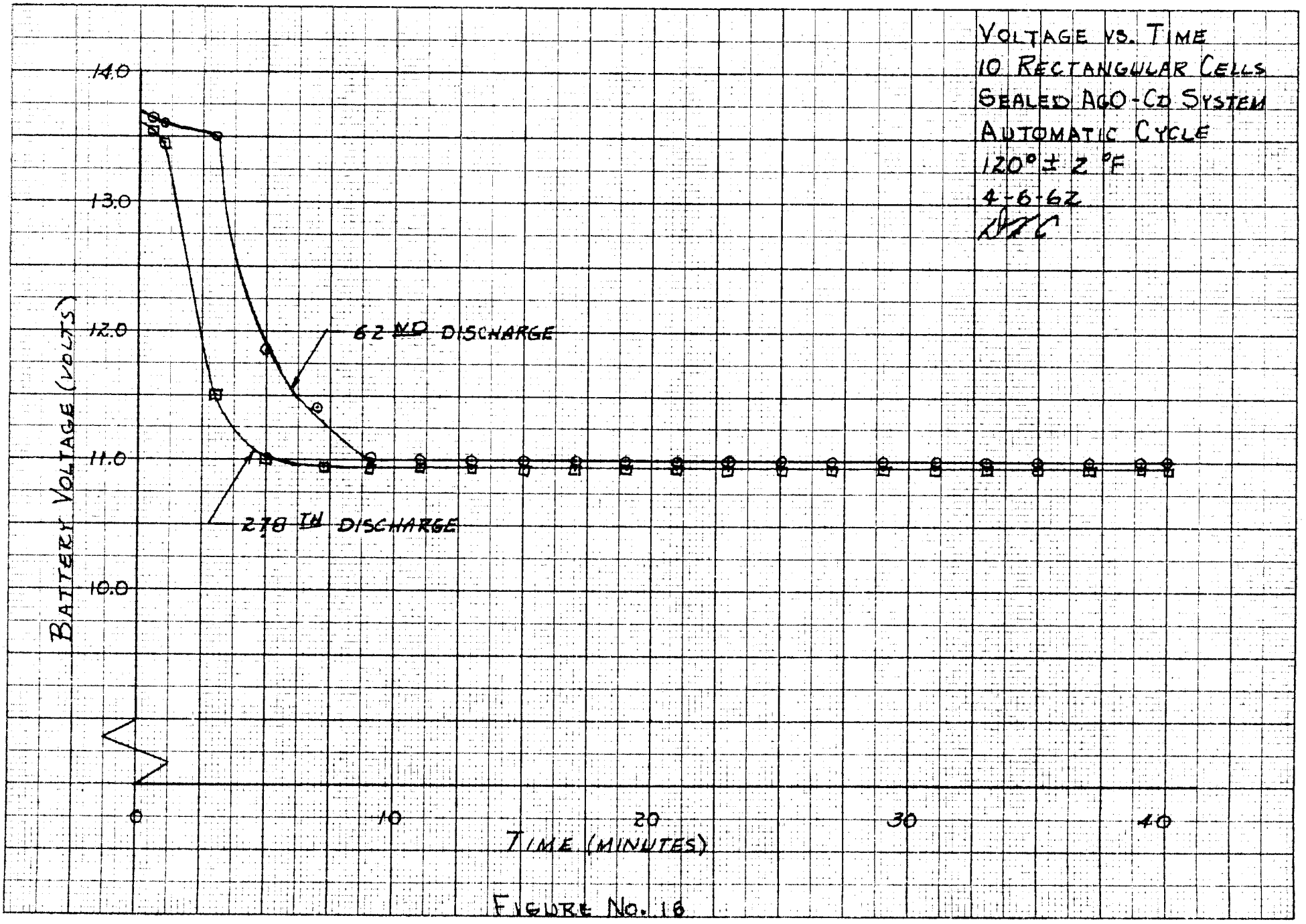

FIGURE No. 16

K+E 10 X 10 TO THE ½ INCH 359-11
KEUFFEL & ESSER CO. MADE IN U.S.A.

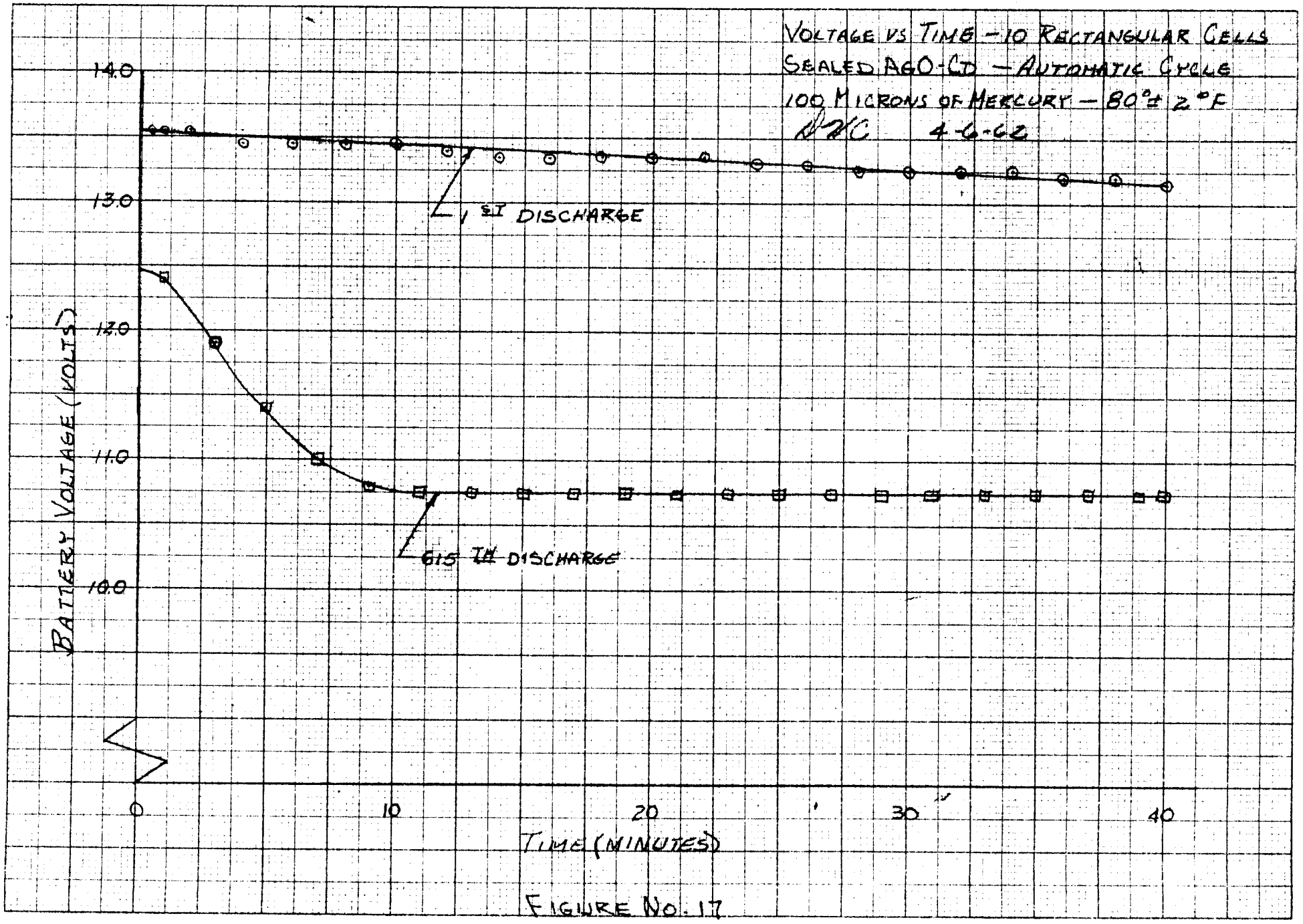

FIGURE No. 17

K+E 10 X 10 TO THE 1/2 INCH 359-11
KEUFFEL & ESSER CO. MADE IN U.S.A.

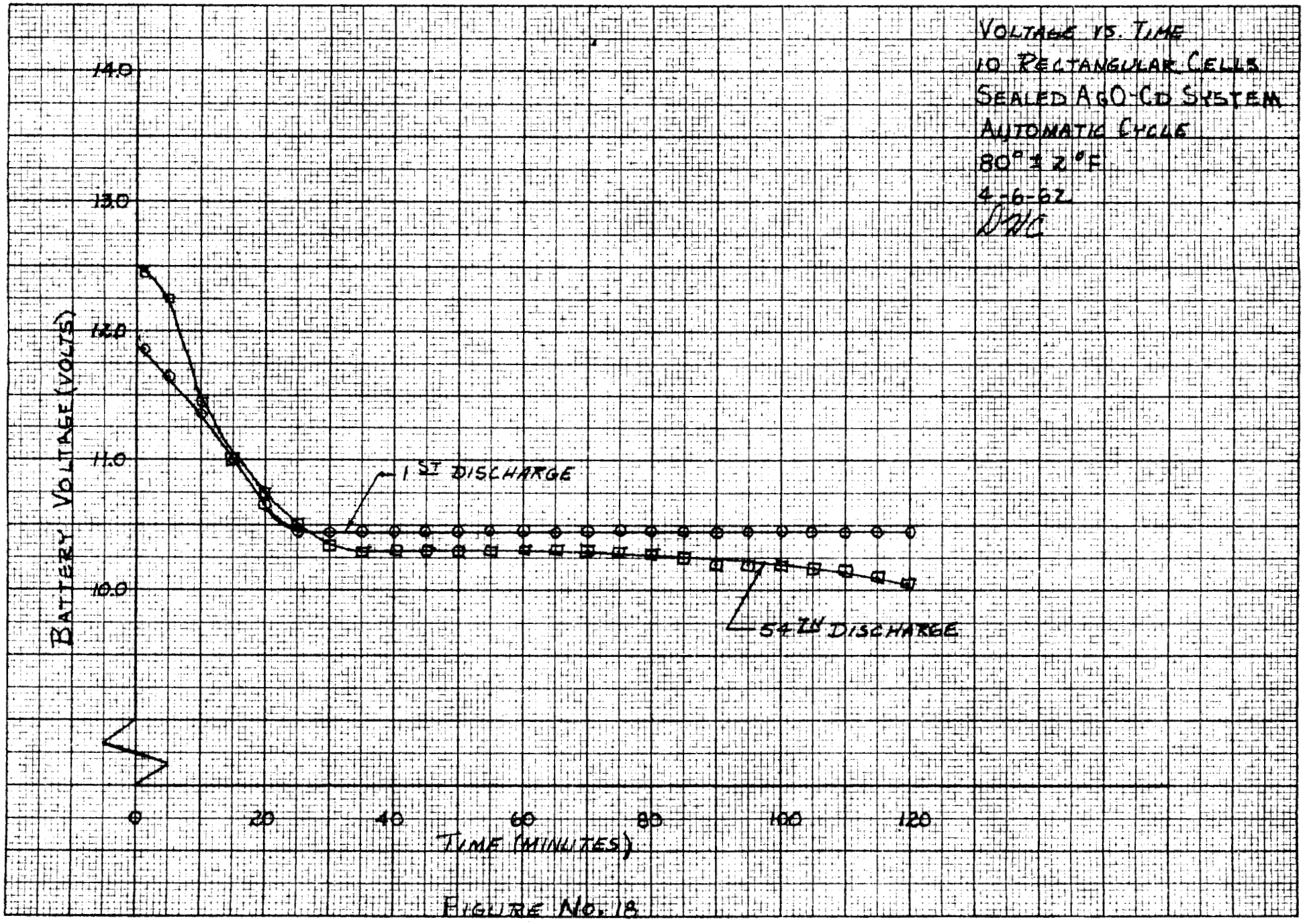

FIGURE No. 18

TABLE NO. IX

CELL CAPACITY COMPARISON - "D" CELLS

Cell No.	Original Capacity (Ampere-Hours)	Capacity After 1329 Cycles (Ampere-Hours)	Percent Capacity Lost
*3	4.70	3.40	27.7
4	4.80	2.40	50.0
6	4.90	3.10	36.7
7	4.90	2.30	53.1
8	5.10	2.60	49.0
11	4.60	3.55	22.8
*12	4.70	4.10	12.7
*16	4.40	4.05	7.8
*19	4.80	4.56	5.1

TABLE NO. X

END-OF-CHARGE AND DISCHARGE CELL VOLTAGE - 20° F

CYCLE NO.	46	47	48	49	50	51	52	53	54	55
1	1.50	1.49	1.50	1.59	1.51	1.50	1.50	1.51	1.49	1.50
	1.08	1.08	1.08	1.08	1.08	1.09	1.08	1.08	1.08	1.08
58	1.50	1.50	1.50	1.49	1.51	1.50	1.50	1.50	1.49	1.50
	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08
204	1.50	1.50	1.50	1.50	1.50	1.51	1.49	1.50	1.50	1.49
	1.08	1.08	1.08	1.08	1.07	1.08	1.08	1.08	1.08	1.08
302	1.50	1.51	1.50	1.51	1.50	1.50	1.51	1.51	1.50	1.50
	1.07	1.07	1.07	1.07	1.06	1.07	1.07	1.07	1.07	1.06
403	1.50	1.515	1.50	1.50	1.50	1.505	1.51	1.51	1.51	1.50
	1.07	1.06	1.07	1.07	1.06	1.07	1.07	1.07	1.07	1.06
504	1.50	1.515	1.50	1.50	1.50	1.50	1.50	1.52	1.52	1.50
	1.06	1.06	1.06	1.07	1.06	1.06	1.06	1.06	1.06	1.06
605	1.50	1.50	1.50	1.50	1.49	1.49	1.50	1.51	1.51	1.50
	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06
706	1.50	1.50	1.49	1.50	1.50	1.50	1.50	1.51	1.51	1.49
	1.06	1.06	1.06	1.06	1.05	1.06	1.06	1.06	1.06	1.05
807	1.50	1.51	1.49	1.50	1.50	1.49	1.49	1.51	1.51	1.50
	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06
922	1.50	1.51	1.49	1.49	1.49	1.49	1.50	1.51	1.51	1.50
	1.05	1.06	1.06	1.06	1.05	1.06	1.06	1.06	1.06	1.05

TABLE NO. XI

END-OF-CHARGE AND DISCHARGE CELL VOLTAGE - 120° F

CYCLE NO.	36	37	38	39	40	41	42	43	44	45
1	1.50	1.52	1.49	1.51	1.48	1.50	1.50	1.49	1.52	1.49
	1.12	1.12	1.12	1.12	1.11	1.12	1.11	1.12	1.12	1.12
102	1.49	1.54	1.48	1.53	1.48	1.52	1.49	1.48	1.54	1.47
	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10
267	1.48	1.61	1.44	1.60	1.44	1.59	1.48	1.46	1.65	1.44
	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10
305	1.64	1.46	1.44	1.46	1.46	1.66	1.66	1.45	1.45	1.44
	1.09	1.10	1.10	1.10	1.10	1.09	1.10	1.10	1.10	1.09
406	1.44	1.64	1.44	1.58	1.62	1.63	1.44	1.44	1.44	1.43
	1.10	1.08	1.10	1.08	1.07	1.06	1.10	1.10	1.10	1.10
493	1.43	1.64	1.44	1.44	1.43	1.59	1.64	1.44	1.59	1.44
	1.09	1.09	1.10	1.09	1.09	1.07	1.08	1.09	1.07	1.10
609	1.43	1.64	1.43	1.45	1.57	1.28	1.56	1.44	1.57	1.64
	1.09	1.09	1.09	1.08	1.04	1.07	1.07	1.09	1.09	1.04

TABLE NO. XII

END-OF-CHARGE AND DISCHARGE CELL VOLTAGE - VACUUM TEST

CYCLE NO.	11	12	13	14	15	16	17	18	19	20
18	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08
103	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08
204	1.50	1.49	1.51	1.50	1.50	1.49	1.50	1.51	1.50	1.50
	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08
306	1.50	1.50	1.49	1.49	1.51	1.49	1.50	1.51	1.51	1.50
	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08
408	1.51	1.51	1.50	1.49	1.50	1.49	1.50	1.50	1.50	1.50
	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08
512	1.51	1.50	1.51	1.49	1.50	1.49	1.51	1.50	1.50	1.49
	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08
601	1.51	1.51	1.51	1.49	1.50	1.49	1.49	1.50	1.51	1.49
	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08

TABLE NO. XIII

END-OF-CHARGE AND DISCHARGE CELL VOLTAGE - 100% DEPTH

CYCLE NO.	1	2	3	4	5	6	7	8	9	10
1	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.51	1.49	1.50
	1.04	1.04	1.04	1.03	1.04	1.04	1.04	1.04	1.03	1.04
12	1.54	1.55	1.46	1.50	1.46	1.52	1.46	1.54	1.53	1.46
	1.04	1.04	1.04	1.05	1.03	1.04	1.04	1.04	1.04	1.03
24	1.50	1.49	1.50	1.51	1.52	1.49	1.51	1.50	1.50	1.49
	1.04	1.03	1.04	1.03	1.04	1.03	1.04	1.04	1.04	1.04
30	1.49	1.50	1.50	1.51	1.49	1.48	1.51	1.49	1.50	1.52
	1.03	1.03	1.04	1.03	1.04	1.02	1.04	1.04	1.03	1.04
48	1.48	1.48	1.49	1.53	1.52	1.48	1.52	1.50	1.50	1.53
	1.03	1.02	1.03	1.04	1.04	1.00	1.03	1.03	1.03	1.03

TABLE NO. XIV

Cycle No.	Cell No.	Weight of Sintered Silver	Charging Voltage	Output (A.H.)	Theoretical Divalent Silver Oxide Output (A.H.)	Percent Efficiency
1	1	50.2 gms.	1.50	10.60	21.59	49.2
1	2	50.2 gms.	1.70	18.40	21.59	85.5
2	1	50.2 gms.	1.50	11.55	21.59	53.6
2	2	50.2 gms.	1.70	19.01	21.59	88.2
3	1	50.2 gms.	1.50	11.46	21.59	53.2
3	2	50.2 gms.	1.70	18.94	21.59	88.0
4	1	50.2 gms.	1.50	10.74	21.59	49.8
4	2	50.2 gms	1.70	18.63	21.59	86.5
5	1	50.2 gms.	1.50	10.05	21.59	48.7
5	2	50.2 gms	1.70	18.10	21.59	84.0